RI 7849

Bureau of Mines Report of Investigations/ 1974

Methane and Dust Controls for Longwalls: Pocahontas No. 3 Coalbed, Grundy, Va.

UNITED STATES DEPARTMENT OF THE INTERIOR

Report of Investigations 7849

Methane and Dust Controls for Longwalls: Pocahontas No. 3 Coalbed, Grundy, Va.

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UNITED STATES DEPARTMENT OF THE INTERIOR
Rogers C. B. Morton, Secretary

BUREAU OF MINES
John D. Morgan, Jr., Acting Director

The work upon which this report is based was done under a cooperative agreement between the Bureau of Mines, U.S. Department of the Interior, and Island Creek Coal Co.

This publication has been cataloged as follows:

Cetinbas, Abdurrahman

Methane and dust controls for longwalls: Pocahontas no. 3 coalbed, Grundy, Va., by Abdurrahman Cetinbas [and others. Washington] U.S. Bureau of Mines [1974]

16 p. illus., tables. (U.S. Bureau of Mines. Report of investigations 7849)

Based on work done in cooperation with the Island Creek Coal Company.

1. Methane. 2. Coal mines and mining—Dust control. 3. Mine dusts. I. U.S. Bureau of Mines. II. Indian Creek Coal Co. III. Title. (Series)

TN23.U7 no. 7849 622.06173

U.S. Dept. of the Int. Library

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METHANE AND DUST CONTROLS FOR LONGWALLS: POCAHONTAS NO. 3 COALBED, GRUNDY, VA.

by

Abdurrahman Cetinbas,[1] R. P. Vinson,[2] Joseph Cervik,[3] and M. G. Zabetakis[4]

ABSTRACT

The periphery of longwall panels in the Pocahontas No. 3 coalbed is characterized by a zone of reduced permeability that inhibits the natural drainage of methane. A residual gas pressure of 105 psig was measured after 1 year in an isolated block of coal measuring 340 by 1,100 feet. The buildup of gas pressure within such large blocks causes methane problems during plowing operations. However, natural drainage holes drilled during development have been found to reduce the gas content of the coal in this coalbed by over 90 percent.

The effect of water infusion on dust during plowing operations was investigated using existing methane drainage holes. These holes were cleaned of debris and a pipe was grouted into the hole for water infusion of the panel. Both total and respirable dust levels were reduced by 40 to 79 percent. Water infusion of the panel proved more effective than did the use of a plow-mounted spray system.

INTRODUCTION

Water infusion of longwall faces to suppress dust is a common practice in European mines. Approximately 13 percent of all such faces in Great Britain[5] and over 50 percent of those in Germany[6] are being infused. In the United States, the longwall mining method[7] accounted for about 1.4 percent of the coal produced during 1971 (3 percent of underground production). Serious dust problems were encountered with some of the installations because of rapid face advance rates, and the friable nature of the coal, and the large air volumes introduced to the confined area of the face.

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[1]Mining engineer.
[2]Physicist.
[3]Supervisory geophysicist.
[4]Supervisory research chemist.
[5]Gregson, H. Deep Hole Infusion in the Kent Coal Field. Colliery Guard., v. 212, No. 5482, May 13, 1966, pp. 599-609
[6]Schlick, D. P. Respirable Dust Control in the Mines of West Germany. BuMines IC 8490, 1970, 16 pp.
[7]Schlick, D. P. Longwall Mining. Coal Age, v. 77, No. 7, July 1972, pp. 138-141.

Morton[8] found the European technique of drilling 30-foot infusion holes spaced 30 feet across the face could not be adopted in water infusing longwall faces in the Eagle coalbed at Carbon Fuel Co. No. 20 mine at Carbon, W. Va., because rapid face advance rates of 30 to 40 feet per day precluded incorporating the drilling and infusion phases into the mining cycle. Consequently, holes up to 200 feet in length were drilled from the sides of the panel parallel to the face. These were used to infuse 5 to 15 gallons of water per minute at pressures between 200 and 600 psi. The results of this work indicated this is an effective and economical means of controlling airborne dust created by mining operations on a longwall face.[9] The water improved the visibility along the face, increased the cutting rate of the plow, and aided greatly in controlling float dust in the return airways and along the belt conveyor used to transport the coal.

The present study in the Pocahontas No. 3 coalbed was designed to yield quantitative data on the effects of water infusion on methane and respirable and total dust. In addition, consideration was given to the incorporation of the infusion technique into the longwall operation.

ACKNOWLEDGMENTS

The cooperation of Island Creek Coal Co., Cleveland, Ohio, during the course of this study is greatly appreciated. The authors thank Luther Preston, superintendent, and William Delomas, mine foreman, Beatrice mine, for their assistance and cooperation in conducting the work described in this report. We acknowledge the assistance of W. H. Sutherland, Coal Mine Health and Safety District 5, in collecting dust samples and T. C. Ruppel, Pittsburgh Energy Research Center, for supplying the sorption curves for the Pocahontas No. 3 coalbed.

CHARACTERISTICS OF THE POCAHONTAS NO. 3 COALBED

The Pocahontas No. 3 coalbed is a highly fractured, friable, and dusty coalbed. Fracture spacing is of the order of 1/4 inch. Depth of cover of the coalbed in the study area varied from about 1,300 feet at valley floors to 2,500 feet in mountainous areas. The gas pressure within the coalbed is high; figure 1 is a plot of the pressure measured at various depths from the coal face. These measurements were made in a section developing into virgin coal. The virgin gas or reservoir pressure of the coalbed was found to be about 660 psig; this corresponds to a hydrostatic head of about 1,550 feet.

Normally, during development mining, the face is advanced in 20-foot increments. At the end of each advance, a steep pressure gradient is established which results in an increase gas flow.[10] Figure 2 shows the quantity

[8] Morton, H. C. Try Water Infusion. Coal Min. and Processing, v. 4, No. 8 August 1967, pp. 48-50, 64-65.

[9] Phillips, Claude E. Water Infusion of Longwall and Conventional Faces, Nat. Safety Council Trans., 57th Cong., v. 7, 1969, pp. 23-26.

[10] Cervik, Joseph. An Investigation of the Behavior and Control of Methane Gas. Min. Cong. J., v. 53, No. 7, July 1967, pp. 52-57.

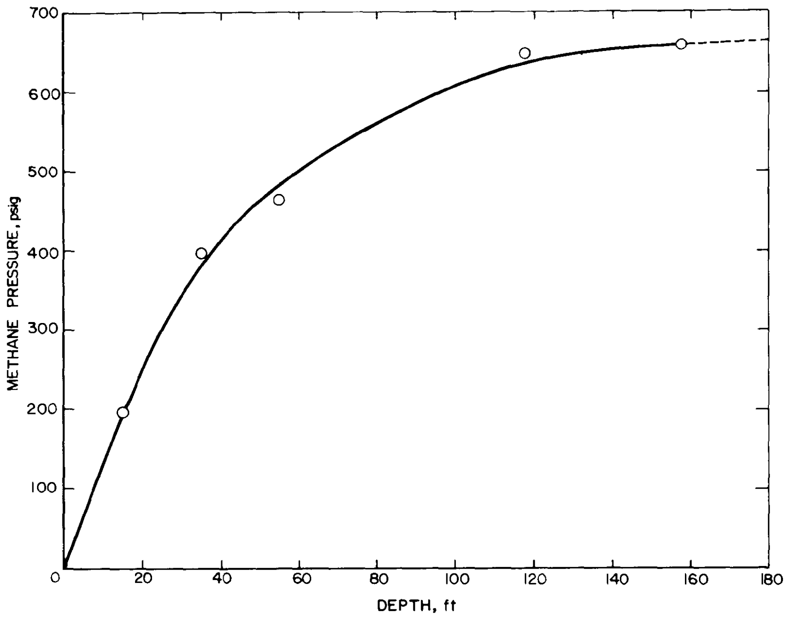

FIGURE 1. - Gas pressure in Pocahontas No. 3 coalbed.

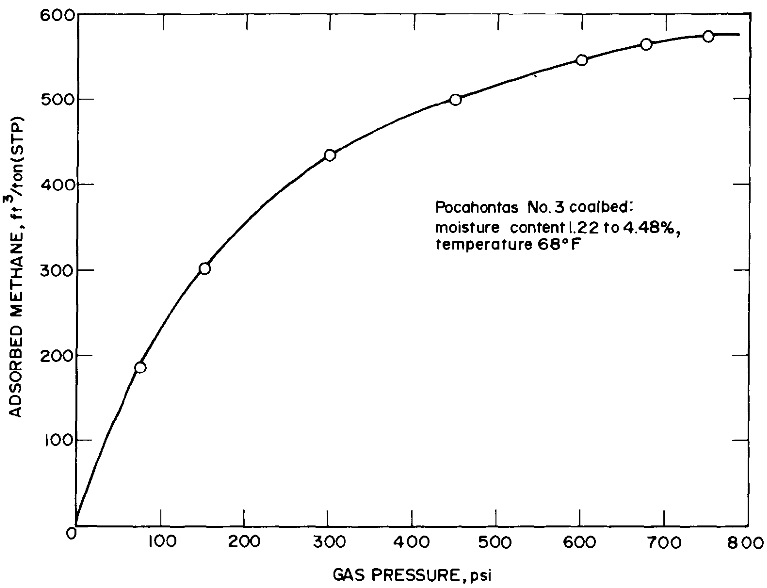

FIGURE 2. - Adsorbed gas versus gas pressure in Pocahontas No. 3 coalbed.

of methane adsorbed in moist Pocahontas No. 3 coal as a function of gas pressure; at 660 psi, the coal contains about 560 (STP) cubic feet of methane per ton of coal. In addition, about 21 cubic feet of gas per ton at standard conditions is contained in the fractures, assuming a fracture porosity of 2 percent. Therefore, in virgin coal no more than approximately 3.6 percent of the total methane content of the coalbed exists in the fracture system as a compressed gas; 96.4 percent exists in the matrix as adsorbed gas. Although 3.6 percent is a relatively small amount of methane, this compressed gas is the gas that causes ventilation problems initially during mining; flow through fractures is a very rapid mode of gas transport as compared with diffusion through the solid coal.

Mine openings in the Pocahontas No. 3 coalbed at depths ranging from 1,300 to 2,500 feet are characterized by a broken, stress-relieved zone about 10 feet deep followed by a highly stressed zone from about 10 to 50 feet. Drilling horizontal holes through the highly stressed zone is difficult. The holes may cave because of the friable nature of the coalbed; often the holes stress relieve and cause the bit and drill pipe to bind.

THE METHANE PROBLEM IN LONGWALLS

The highly stressed zones around mine openings in the Pocahontas No. 3 coalbed also exist around large pillars and longwall panels. The flow of gas through such zones is slowed by the reduced permeability. A horizontal hole drilled into an isolated block of coal measuring 340 by 1,100 feet yielded a gas pressure measurement of 105 psig, despite the fact that this block had been isolated for more than 1 year. A similar problem was encountered when the longwall mining method was first used in this coalbed. The flow of methane from a 273- by 3,800-foot panel posed a severe problem during plowing operations, commonly causing downtime of 2 to 4 hours per shift. This problem was solved by drilling horizontal holes into the panel from the ventilation returns on 100-foot centers. However, considerable difficulty was experienced in drilling through the highly stressed zone surrounding the panel. For this reason the technique was altered to permit the drilling to take place during development of the panel. This procedure is currently used in longwall mining this coalbed. Hole depths vary from about 75 to 220 feet and the holes generally are drilled from both sides of the panel using an auger with 2-1/2-inch bit.

DEVELOPMENT OF A HOLE PACKING AND INFUSION TECHNIQUE

The present study was conducted on a longwall panel 450 feet wide and approximately 3,400 feet long. The panel had been retreated about 900 feet. Figure 3 shows the study area (test site) in relation to the development of the mine; figure 4 shows this same area on a larger scale.

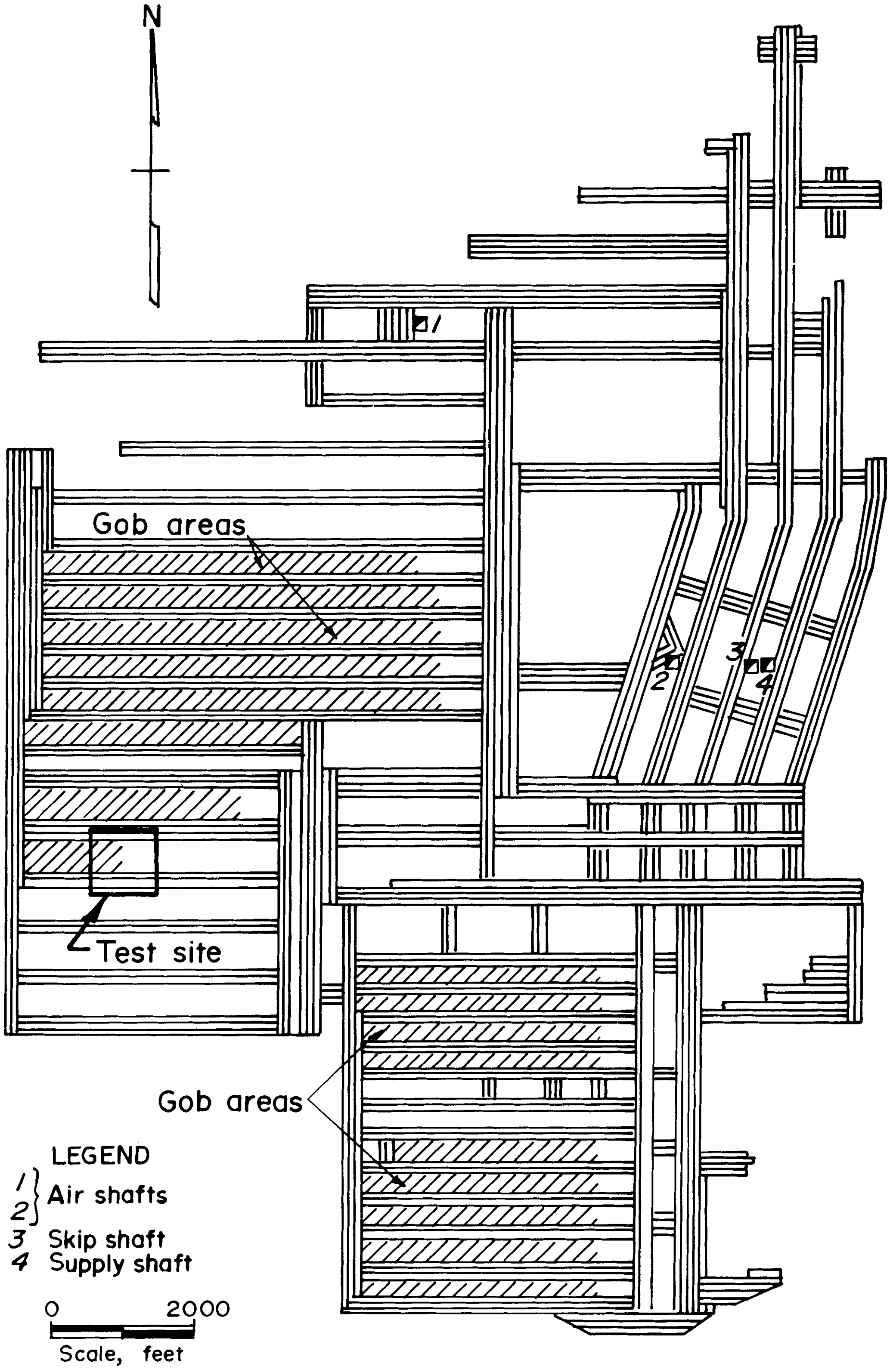

FIGURE 3. - Map of Beatrice mine showing test site.

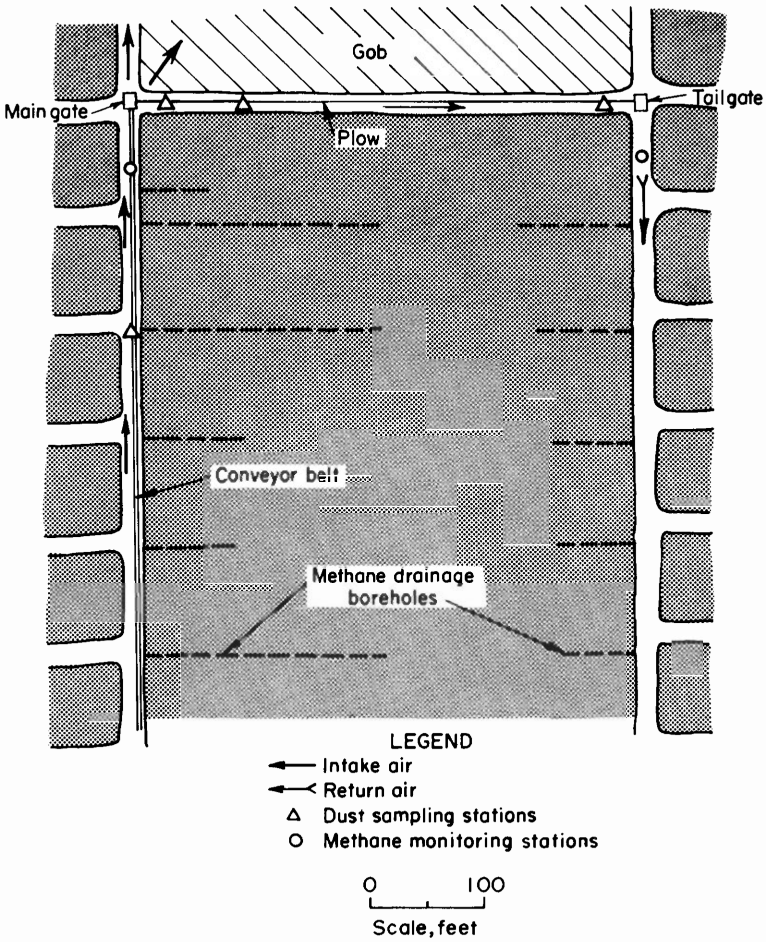

FIGURE 4. - Locations of monitoring stations.

To effectively infuse water into an isolated block of coal such as a longwall panel requires proper packing of the hole along most of its length. Best results are obtained when water is infused from the back of the hole. This procedure prevents premature breakthrough of the water along the panel rib. When breakthrough does occur, the water that is pumped into the panel at the back of the hole comes out along the rib and penetration into the panel stops.

Water infusion of a panel through holes parallel to the face has several advantages over infusion through holes drilled perpendicular to the face:

1. Horizontal holes are already available, as they are now drilled parallel to the face during development to predrain methane.

2. The mining cycle is not interrupted.

3. A highly stressed zone exists at the face so that drilling holes through this zone and setting packers is difficult.

4. Drilling at the face is difficult because of space limitations.

5. The face is characterized by large blocks of loose coal that create unsafe working conditions.

6. Face advance rates on a 450-foot face are about 20 feet per shift. Drilling holes 20 to 30 feet deep at intervals of 30 feet across the face would require at least 15 holes. Incorporating drilling and infusion phases into the mining cycle would be difficult, time consuming, and dangerous, and would interfere with mining.

Two procedures can be used to infuse longwall panels. The holes can be packed with retrievable inflatable packers, or pipe can be grouted into the holes. Initial attempts were made to ream the existing 2-1/2-inch-diameter holes to 3 inches so that 2-5/8-inch-diameter inflatable packers could be used for infusion. These holes collapsed as drilling progressed and this approach was abandoned. Attempts then were made to drill new 3-inch-diameter holes; the coal around the holes stress relieved and collapsed. The use of inflatable packers was abandoned and a grouting procedure was developed using the existing 2-1/2-inch-diameter methane drainage holes. Because the methane drainage holes generally were filled with debris, they were first cleaned by water flushing using the mine's 750-psig water supply. Next, a washer-pipe assembly (fig. 5) was centered in the hole and grouted in place. An expanding-type grout was used, consisting of a blend of 50 percent class A portland cement and 50 percent gypsum cement by volume. Salt is added to the slurry to extend pumping time and improve bonding characteristics. An organic chemical dispersant such as CFR-2[11] is added to reduce frictional flow pressures and slow down setting time. As an example, a typical slurry may consist of one sack of class A portland cement, one sack of gypsum cement, 10-1/2 gallons of water, 8 pounds of salt, and 2 pounds of CRF-2. This slurry will set in approximately 40 minutes.

MONITORING INSTRUMENTS AND PROCEDURES

Methane

Methane and air measurements were made with a combined anemometer-methanometer developed under contract by the Bacharach Instrument Co. (fig. 6). This instrument automatically samples, measures, records, or displays on dials the methane and air volumes that pass through a specific location. If desired, the methane concentration and air velocity can be recorded also. Two of these instruments were used to monitor methane and airflow at the maingate and tailgate about 50 feet from the face (fig. 4). Their sensing heads were located at the points found to have the average air velocity.

Dust

Dust samples were collected with MSA Monitaire Model G personal samplers and MRE gravimetric-type 113A dust samplers. Total dust samples for contrast with respirable dust were obtained by removing the cyclones from the MSA samplers.

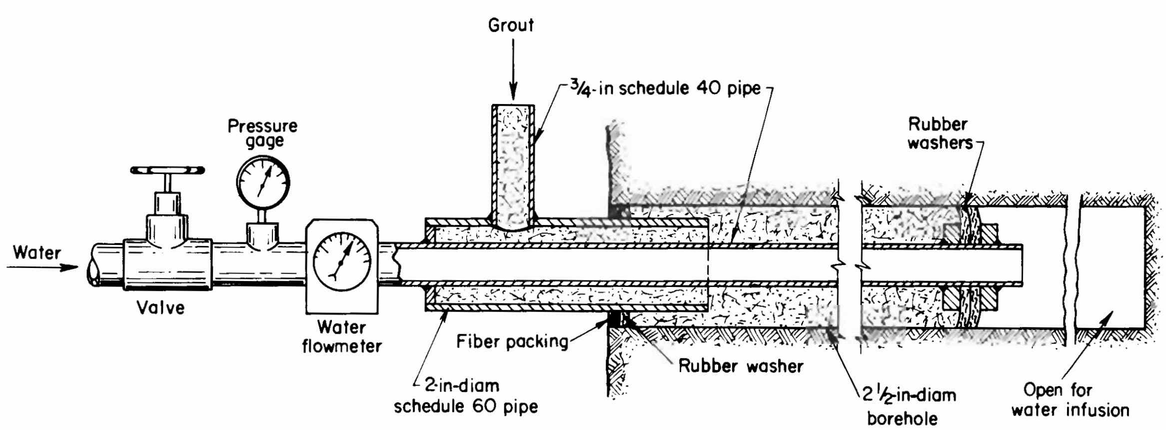

FIGURE 5. - Schematic of washer-pipe assembly used for water infusion of a longwall panel.

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[11]Reference to specific company or trade names is made for identification only and does not imply endorsement by the Bureau of Mines

FIGURE 6. - Combined anemometer-methanometer instrument package.

Dust was sampled at five different periods during this study. All dust samplers were operated only at the sampling locations. The length of time a dust sampler was in operation was the time used in calculating the final dust concentration. These calculations were made in accordance with procedures developed by the Bureau's Pittsburgh Field Health Group.[12] In order to compare various sampling periods, dust concentrations were normalized by dividing by the weight (tons) of coal mined during each sampling period. Except for the dust survey of the first infused zone, both total and respirable dust measurements were taken at every sampling station. Sampling stations have been designated intake, maingate, 100 feet downface, and tailgate (fig. 4). Intake samplers were positioned approximately 200 feet outby the face. Maingate samplers were located 25 feet down the face from the maingate and attached to one of the hydraulic jacks; the 100-foot-downface samplers were located 100 feet down the face from the maingate. Tailgate locations refer to samplers placed 25 feet up the face from the tailgate.

RESULTS AND DISCUSSION

Methane

Methane concentrations and air velocities were recorded continuously at a location approximately 50 feet ouby the tailgate in the return. Figure 7 shows a typical methane concentration and air velocity recording. The peaks and troughs shown on the methane record are due to the relative velocity between the plow and ventilation current. Peaks on the methane curve were obtained when plowing toward the tailgate in the same direction as the airflows. The methane released by broken coal and the fracture system of the

[12] U.S. Bureau of Mines. Sampling and Evaluating Respirable Coal Mine Dust. A Training Manual. IC 8503, 1971, 47 pp.

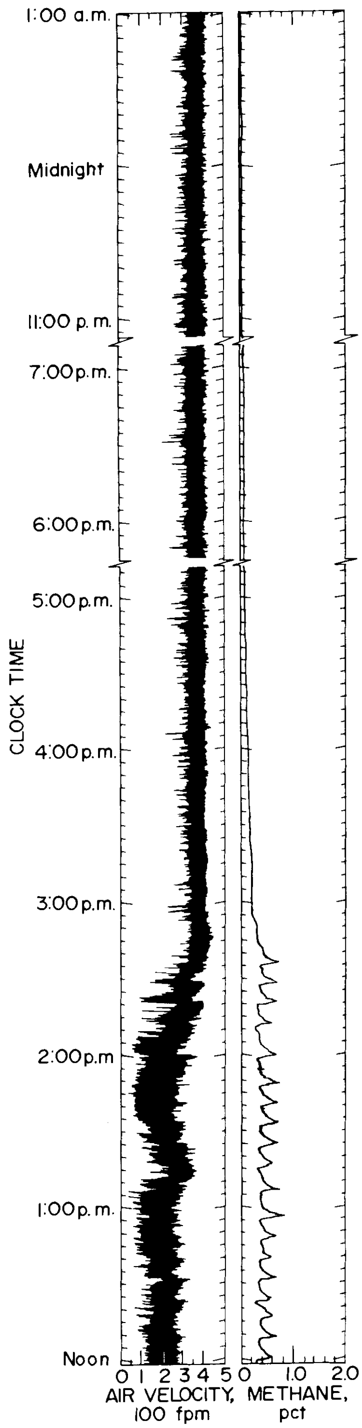

FIGURE 7. - Methane concentration and air velocity recordings.

panel traveled with the plow and, consequently, the concentration of methane increased. The average speed of the plow was 100 fpm (feet per minute) and the measured air velocities in the vicinity of the plow ranged from 400 to 500 fpm. The troughs on the methane curve were obtained when the plow traveled toward the maingate when the relative velocity was greatest so the concentrations of methane are lowest.

Examination of figure 7 shows that the methane measured in the immediate return comes from the longwall panel. About 2 to 3 hours after plowing ceased, the methane concentration in the air dropped to about 0.05 percent methane--the level of methane in the intake air. There appeared to be no methane coming from the gob in this area.

Taking an average methane concentration of 0.5 percent during plowing operations, an average air velocity of 200 fpm, and a cross-sectional area of 90 square feet at the measurement point, the volume flow of methane from the panel would be 90 cfm (cubic feet per minute). During a 6-hour plowing time about 2,000 tons of coal was mined. For this mining period, methane was liberated at a rate of 16.2 cubic feet per ton of coal.

The back-and-forth movement of the plow during mining influences the ventilation current as shown in the air velocity recording in figure 7. Note the fluctuations in air velocity during plowing operations compared to the variations after the plow is stopped. Also, the envelope of the air velocity recording has peaks and troughs that correlate with the peaks and troughs of the methane recording. When the plow is traveling toward the tailgate, air velocity increases, and during this time interval the methane concentration reaches its peak also.

Water infusion has no appreciable effect on methane emission while mining the panel. However, only a relatively small volume of the panel was infused near the maingate. To reduce methane flows further would require the emplacement of a waterbank the width of the panel. Figure 7 shows that there is some methane bleed-off from the panel after plowing stopped. The fact that methane concentration maximums did not exceed 0.8 percent during plowing demonstrates the effectiveness of the drainage holes drilled into the panel during development as a methane control measure.

Dust

Before the infusion tests were conducted various dust control measures were used. During mining, the face was sprayed continuously at approximately 90 points, using nozzles mounted on spillplates. Water sprays also were used at the inby transfer point (face conveyor to stage loader) and at the entry and exit of the coal breaker. A wetting agent was metered into the mine's water supply to increase the dust-suppression ability of the water. The outby transfer point (stage loader to conveyor belt) was covered with a hook constructed of angle iron and plastic sheet to contain the airborne dust at this location. These dust controls were in use during the first four sampling periods. During the fifth and final dust survey additional dust controls were used and these will be discussed in context.

The first survey was a base study to determine the dust concentrations at the various sampling stations prior to infusion. Dust samples were taken on the day shift for 4 consecutive days (table 1.) With this information, an average dust concentration was established for each sampling station.

TABLE 1. - Baseline dust survey

Location and date	Dust concentration, mg/m^3		Coal production, tons
	Total	MRE equivalent respirable	
Intake:			
Mar. 8...	3.2	0.6	2,079
Mar. 9...	3.2	.6	2,079
Mar. 10...	2.9	.6	1,881
Mar. 11...	2.9	.6	2,376
Average	3.1	.6	2,104
Maingate:			
Mar. 8...	45.4	8.3	2.079
Mar. 9...	59.1	9.3	2,079
Mar. 10...	60.8	10.6	1,881
Mar. 11...	66.1	10.2	2,376
Average	57.9	9.6	2,104
Tailgate:			
Mar. 8...	([1])	([1])	2,079
Mar. 9...	129.8	14.1	2,079
Mar. 10...	88.5	8.9	1,881
Mar. 11...	119.2	13.9	2,376
Average	112.5	12.3	2,104

[1]Rock dust voided samples.

Because Pocahontas No. 3 coal is highly friable and not very wettable, the dust-suppression effectiveness of water was questionable. To answer this question, a one-shift study was made which involved spraying the first 100 feet of face with three equally-spaced fire nozzles. These nozzles were manually operated and used only when the plow was within spray range. Thus a high volume of water was concentrated at the plow where the concentration of dust was greatest. While the face was being sprayed in this manner, dust was being sampled at three locations--all within the first 100 feet of face. A significant reduction in dust levels resulted (table 2).

TABLE 2. - Fire nozzle test

	Dust concentration, mg/m^3		Reduction from base average, percent	
	Total	MRE equivalent respirable	Total	MRE equivalent respirable
Maingate..	40.0	7.0	31	27
Downface:				
70 feet.	32.2	4.0	44	58
75 feet.	36.3	4.5	37	53

The first dust survey of an infused zone was made as the face approached infusion hole A1 (table 3). This was a 220-foot hole which had been grouted to a depth of 85 feet (table 4). Approximately 4,400 gallons of water were forced into the coal through this hole. Since the face was 450 feet long, only the first half of the panel was adequately flooded. A schematic of the face area (fig. 8) shows the location of the face with respect to the infusion hole at the beginning of each sampling shift. The histograms (figs. 9 and 10) show total and respirable dust concentration per ton at the maingate and tailgate sampling stations and a decline in dust content of the air as the face neared the infusion hole. The unusally low dust concentrations at the maingate on March 30 were due in part to another experiment. On this date, brattice cloth was placed along the panline for 50 feet to keep dust created by the plow from entering air around the jacks.

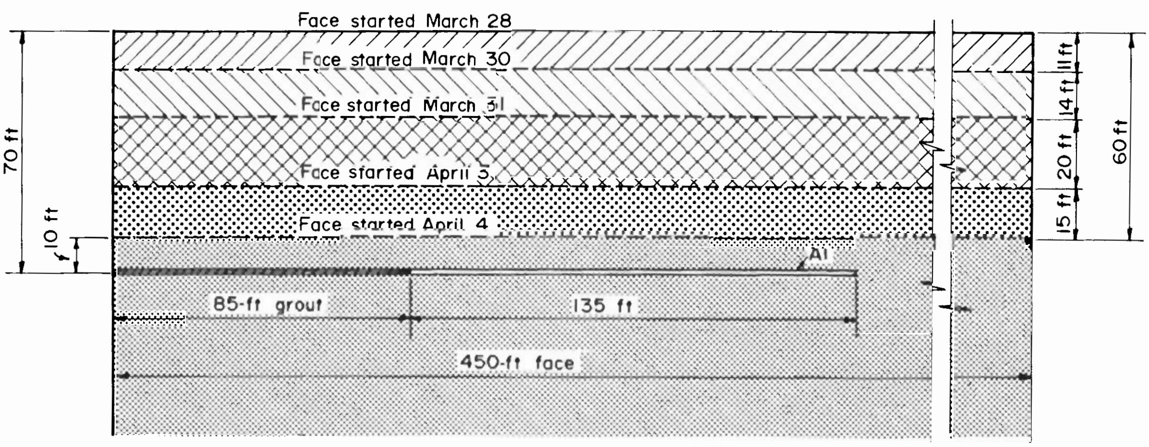

FIGURE 8. - Face advance near borehole A1.

TABLE 3. - Dust survey; borehole A1

Location and date	Dust concentration, mg/m³ Total	Dust concentration, mg/m³ MRE equivalent respirable	Coal production, tons
Intake:			
Mar. 28...	([1])	1.4	[2]800
Mar. 30...	([1])	1.6	1,200
Mar. 31...	([1])	0.9	2,200
Apr. 3...	([1])	.4	2,100
Apr. 4...	([1])	.2	1,900
Maingate:			
Mar. 28...	22.2	7.0	[2]800
Mar. 30...	13.3	1.0	1,200
Mar. 31...	12.3	5.9	2,200
Apr. 3...	19.0	3.5	2,100
Apr. 4...	16.5	1.8	1,900
Tailgate:			
Mar. 28...	([1])	11.2	[2]800
Mar. 30...	37.3	7.3	1,200
Mar. 31...	([1])	9.8	2,200
Apr. 3...	53.5	4.6	2,100
Apr. 4...	53.9	6.6	1,900

[1]No samples taken.
[2]Part-time work.

Table 4. - Water infusion data

Borehole	Depth, feet	Grouted part, feet	Water pressure, average psig	Water flow rate, gpm	Amount of water infusion, gallons
A1	220	85	709	18.2	4,368
A2	220	145	439	3.5	5,758
A3	120	40	600	9.5	1,000
A4	80	50	600	9.5	4,500

The normalized concentrations (mg/m³/ton of coal) taken when the face was 10 feet from the infusion hole compared with the baseline survey shows a pronounced reduction in airborne dust (table 5.) This reduction was greatest at the maingate locations that collected dust produced mainly from the infused portion of the face.

TABLE 5. - Percent of dust reduction; borehole A1[1]

Location	Dust reduced, percent Total	Dust reduced, percent MRE equivalent respirable
Maingate.......	69	79
Tailgate.......	47	40

[1]Face: 10 feet from hole A1.

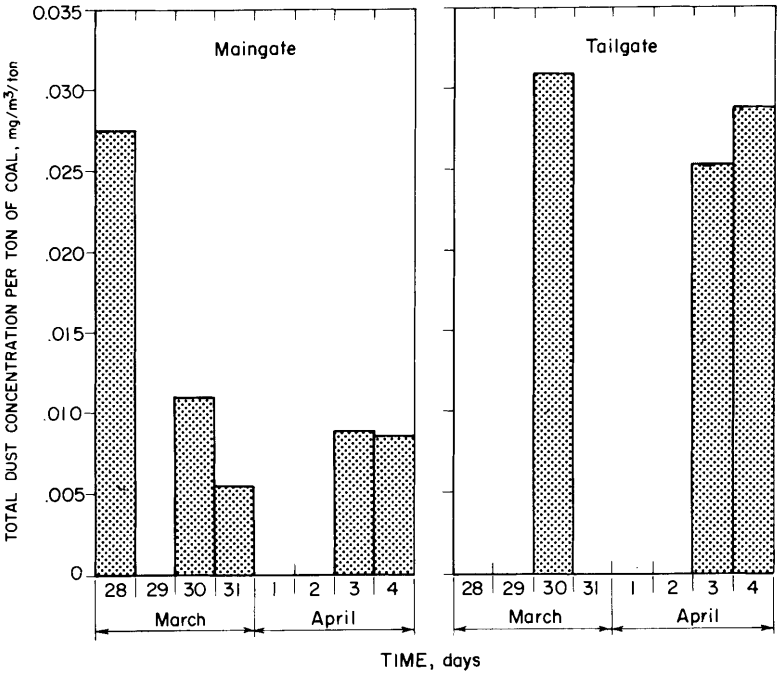

FIGURE 9. - Total dust histograms; borehole A1.

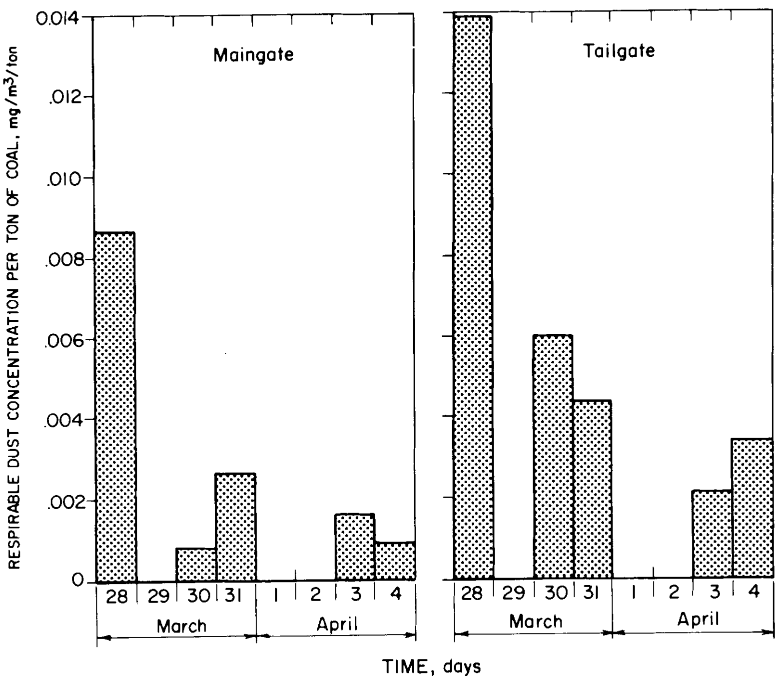

FIGURE 10. - Respirable dust histograms; borehole A1.

The next dust survey took place as the face approached the second infused hole A2. This hole was 220 feet deep, grouted to 145 feet, and infused with 5,800 gallons of water (table 4). Dust was sampled on three shifts. Samplers were placed at intake, maingate, and tailgate sampling stations. During sampling intervals, hazardous roof conditions slowed production to about one-fourth normal. For this reason, it was not possible to ascertain whether the low dust levels were due entirely to low production or in part to water infusion. The samples collected during this period do show that at low production rates the dust concentration approaches a constant level all along the face (table 6.)

A final dust survey (table 7) was made as the face receded from an area infused through two holes--A3 and A4 (table 4). The first hole, A3, was 120 feet deep, grouted to 40 feet, and infused with 1,000 gallons of water. Hole A4 was located 20 feet outby A3 and was infused with 4,500 gallons. This hole was 80 feet deep and grouted to 50 feet. A schematic of the face area during the sampling cycle is shown in figure 11. As the face receded from the infused zone, the histograms (figs. 12-13) show that the dust concentration increased. This same trend also may be seen in the total dust tailgate samples, with one exception (table 7). On the third day of sampling, the measured total dust at the tailgate, when normalized, was lower than that at the maingate and 100-foot downface locations. There was no apparent reason for this low measurement (other than the possibility of a malfunction in the sampler).

TABLE 6. - Dust survey; borehole A2

Location and date	Dust concentration, mg/m^3		Coal production, tons	Remarks
	Total	MRE equivalent respirable		
Intake:				
May 3.....	4.1	0.6	425	Bad roof
May 4.....	4.8	.4	625	Do.
May 5.....	4.5	.5	539	Do.
Average	4.5	.5	530	
Maingate:				
May 3.....	16.4	1.8	425	Do.
May 4.....	18.7	2.2	625	Do.
May 5.....	18.6	2.0	539	Do.
Average	17.9	2.0	530	
Tailgate:				
May 3.....	18.7	2.1	425	Do.
May 4.....	18.0	1.7	625	Do.
May 5.....	18.3	2.1	539	Do.
Average	18.3	2.0	530	

TABLE 7. - Dust survey; boreholes A3 and A4

Location and date	Dust concentration, mg/m^3		Coal production, tons
	Total	MRE equivalent respirable	
Intake:			
July 18...	0.6	0.2	1,260
July 19...	1.4	.4	1,980
July 20...	1.2	.2	[1]990
Maingate:			
July 18...	7.4	1.8	1,260
July 19...	19.9	4.3	1,980
July 20...	14.2	2.5	990
Downface 100 feet:			
July 18...	16.8	2.5	1,260
July 19...	33.8	4.7	1,980
July 20...	21.0	3.4	990
Tailgate:			
July 18...	25.7	([2])	1,260
July 19...	32.8	([2])	1,980
July 20...	13.4	([2])	990

[1]Part-time work.

[2]Faulty respirable samplers.

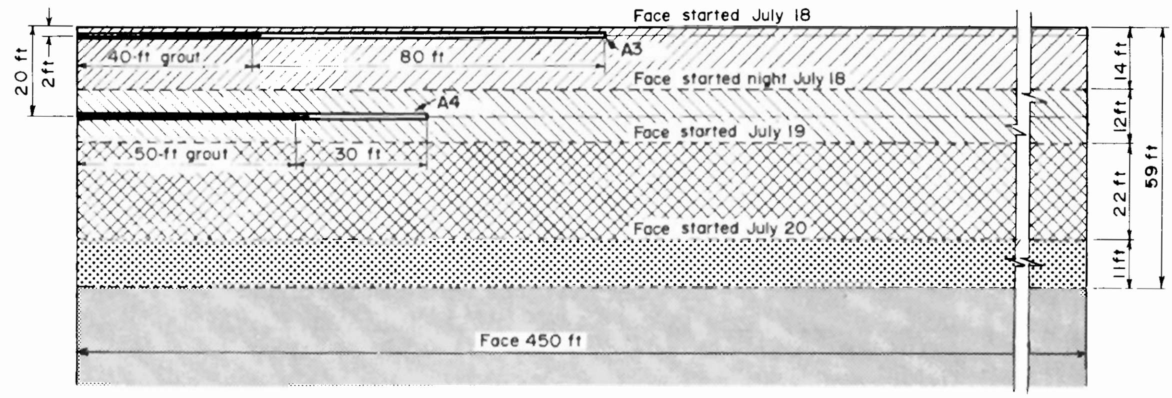

FIGURE 11. - Face advance in area of boreholes A3 and A4.

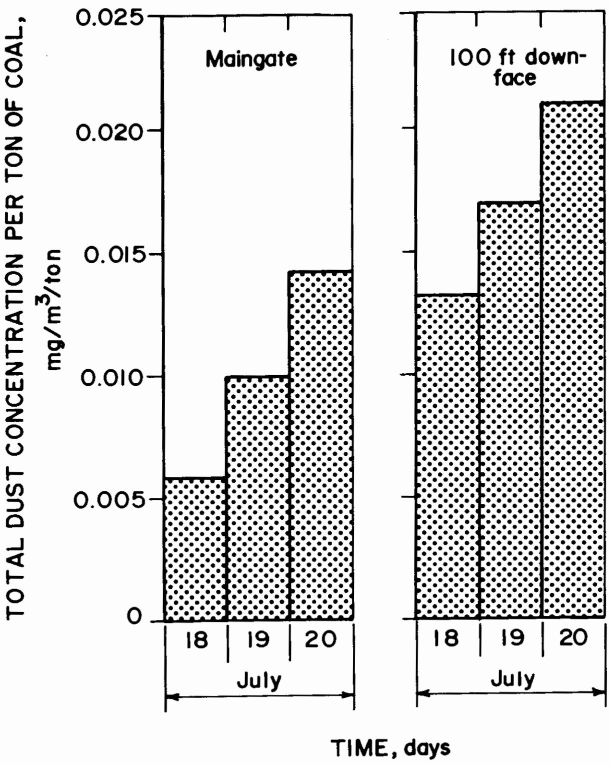

FIGURE 12. - Total dust histograms; boreholes A3 and A4.

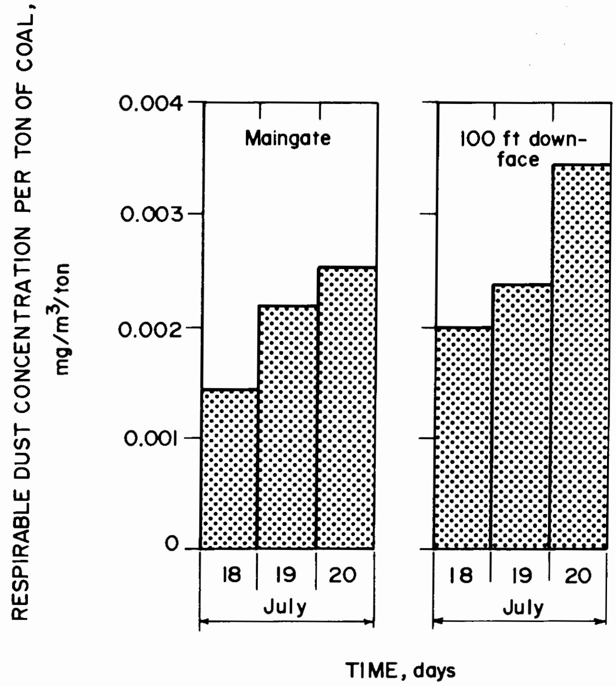

FIGURE 13. - Respirable dust histograms; boreholes A3 and A4.

At the time of this sampling period, additional dust controls had been incorporated into the section. Foam was being applied at the inby transfer point and at the entrance of the coal breaker. Watersprays had been mounted on the plow and were operating. The sprays were mounted vertically, nine on each side of the plow. These dust controls required about 30,000 gallons of water per shift. While the dust samples were being collected, the face passed through an area infused with about 5,500 gallons of water. The ratio of infused to spray water was about 1 to 5. Even with this high ratio the effect of infusion was measurable, as shown by the histograms. A comparison was made between the normalized dust concentrations taken on the first sampling day of this period and the baseline normalized concentrations. The results are found in table 8.

TABLE 8. - Percent of dust reduction; boreholes A3 and A4

Location	Dust reduced, percent	
	Total	MRE equivalent respirable
Maingate.......	78	68
Tailgate.......	62	([1])

[1]Inconsistent measurement.

A comparison of tables 8 and 5 shows that dust concentration decline at the maingate was approximately the same in both surveys. At the tailgate, however, the comparison shows a slightly greater decline in airborne dust during the last survey. At this location, table 8 shows an additional reduction of 15 percent for respirable dust and an additional 24 percent for total dust over that in table 5. The most interesting finding here was that water infusion alone was more effective in suppressing dust than all the other dust controls noted above.

The Pocahontas No. 3 coalbed is highly fractured and friable and apparently the bulk of the dust observed during mining is inherent to the coalbed. If the dust in the fracture system can be wetted before the coal is mined dust can be controlled to acceptable levels. Water infusion is an effective dust suppressant in the Pocahontas No. 3 coalbed because only a small fraction of the dust is generated by breaking blocks of solid coal.

CONCLUSIONS

Water infusion of longwall panels in the Pocahontas No. 3 coalbed is an effective and efficient means of suppressing total and respirable dust. Although the spray system on the plow does suppress airborne dust, it is not as effective as water infusion. The bulk of dust observed during mining is inherent to the coalbed and wetting this dust before mining prevents it from becoming airborne. The effectiveness of water infusion can be increased by infusing the panel from both sides.

Because less than one-half of the panel near the maingate was infused, methane liberation from the longwall face was not affected. The determination of the effect of water infusion on methane requires the whole face to be infused. The levels of methane observed during plowing operations indicate that methane drainage holes drilled into the panel on development are effective in predraining methane.

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